

METHOD AND APPARATUS FOR COUPLING A VOICEBAND MODEM CIRCUIT  
TO A COMMON PHONELINE CONNECTOR

5 CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application claims the benefit of the filing  
date of U.S. Provisional Patent Application No. 60/212,388 filed  
June 19, 2000, the entire contents of which is hereby expressly  
10 incorporated by reference.

BACKGROUND OF THE INVENTION

The present invention relates to the field of voice and  
15 data communications, and in particular, a method and apparatus  
for coupling a voiceband modem circuit to a common phoneline  
connector for use in a home network communications system.

20 Referring to Figs. 1a - 1e, an evolution of home based  
communications systems is depicted.

In Fig. 1a, plain old telephone service (POTS) wiring 102,  
generally unshielded twisted pair (UTP) wiring, at customer  
25 premises 104 couples POTS telephones 106 through subscriber loop  
108 to a telephone company central office, which, in turn, is  
connected to the public switched telephone network (PSTN).  
Customer premises 104 is a telephone subscriber site that has  
30 arranged (generally for a monthly telephone service fee or for  
a per call minute fee) with a local provider (such as a local  
telephone company) for a connection to the central office. The  
central telephone office (also called a local exchange) provides  
local switching and non-local switching via the PSTN.

35 In Fig. 1b, computer 110 through conventional voice modem  
112 can also be coupled to POTS wiring 102 to allow the  
transmission of signals from computer 110 to be transmitted onto

the telephone network. Voice modem 112 will be described in more detail below.

In Fig. 1c, there is depicted a conventional local area network (LAN) 114 (such as an ethernet network using coaxial cable) installed at customer premises 104 in addition to any POTS wiring 102 that may be in place to connect, for example, computer 110 with computer 110a.

In Fig. 1d, computers 110 and 110a, rather than being connected via LAN 114 as seen in Fig. 1c, connects and utilizes POTS wiring 102 as a LAN transmission medium in accordance with the Home Phoneline Network Alliance (HPNA) specifications for the LAN computer interconnection over existing telephone lines within the local environment.

In Fig. 1e, computer 110, while implementing an HPNA LAN via POTS wiring 102, can also implement broadband digital data services through digital subscriber line (xDSL) modem 116, including one which supports asymmetrical digital subscriber line (ADSL) protocol, coupled to POTS wiring 102.

While broadband data services using DSL, or similarly cable modem or fixed wireless transceivers, are now being regularly deployed in home environments, there is still a need for basic connectivity using legacy voiceband data modems. Moreover, in the case of DSL and particularly ADSL, the broadband service may use the same physical metallic pair over which the voiceband modem signals travel to the PSTN central office, though at higher frequencies. In many cases, there may be no splitter (low-pass filter) between the in-premise wiring and the local loop.

Therefore, a need exists for a method and apparatus for attenuating high-frequency interfering signals, such as splitterless ADSL or phoneline network signals, at the front-end

of a voiceband modem. The present invention provides a solution to this problem and will enable low-cost voiceband modems which use line-powered DAAs to be able to effectively connect to the PSTN.

5 SUMMARY OF THE INVENTION

10 In accordance with the present invention a method and apparatus for coupling a voiceband modem circuit to a common phoneline connector is provided, the common phoneline connection having a ring line connection and a tip line connection which couples a ring/tip line pair to a subscriber loop circuit, the voiceband modem circuit operating in a voiceband modem operating frequency band and having a voiceband modem interface ring line  
15 and a voiceband modem interface tip line.

20 In particular, in one embodiment of the present invention the voiceband modem interface ring line is coupled to the ring line and the voiceband modem interface tip line is coupled to the tip line connection by inserting, between the ring line connection and the voiceband modem interface ring line and between the tip line connection and the voiceband modem interface tip line, a series pair of inductors. A first inductor of the  
25 series pair has a low inductance and a high self-resonant frequency and a second inductor of the series pair has a high inductance and low self-resonant frequency. The low inductance, the high self-resonant frequency, the high inductance and the low self-resonant frequency are each determined to locate a filtering  
30 cutoff point between the voiceband modem operating frequency band and a digital subscriber line operating frequency band.

35 In another embodiment a method and apparatus for coupling a voiceband modem circuit and a digital subscriber line circuit to a common phoneline connector is provided, the common phoneline connection having a ring line connection and a tip line

connection which couples a ring/tip line pair to a subscriber loop circuit, the voiceband modem circuit operating in a voiceband modem operating frequency band and having a voiceband modem interface ring line and a voiceband modem interface tip line, the digital subscriber line circuit operating in a digital subscriber line operating frequency band and having a digital subscriber line interface ring line and a digital subscriber line interface tip line. The voiceband modem interface ring line and the digital subscriber interface ring line are coupled in parallel to the ring line. The voiceband modem interface tip line and the digital subscriber interface tip line are coupled in parallel to the tip line connection. The coupling the voiceband modem interface ring line and the coupling the voiceband modem interface tip line is by inserting, between the ring line connection and the voiceband modem interface ring line and between the tip line connection and the voiceband modem interface tip line, a series pair of inductors. A first inductor of the series pair has a low inductance and a high self-resonant frequency and a second inductor of the series pair has a high inductance and low self-resonant frequency. The low inductance, the high self-resonant frequency, the high inductance and the low self-resonant frequency are each determined to locate a filtering cutoff point between the voiceband modem operating frequency band and the digital subscriber line operating frequency band.

In still another embodiment a method and apparatus for coupling a voiceband modem circuit and a home phonenumber circuit to a common phonenumber connector is provided, the common phonenumber connection having a ring line connection and a tip line connection which couples a ring/tip line pair to a subscriber loop circuit, the voiceband modem circuit operating in a voiceband modem operating frequency band and having a voiceband modem interface ring line and a voiceband modem interface tip line, the home phonenumber circuit operating in a home phone line

operating frequency band and having a home phoneline interface ring line and a home phoneline interface tip line. The voiceband modem interface ring line and the home phoneline interface ring line are coupled in parallel to the ring line. The voiceband modem interface tip line and the home phoneline interface tip line are coupled in parallel to the tip line connection. The coupling the voiceband modem interface ring line and the coupling the voiceband modem interface tip line is by inserting, between the ring line connection and the voiceband modem interface ring line and between the tip line connection and the voiceband modem interface tip line, a series pair of inductors. A first inductor of the series pair has a low inductance and a high self-resonant frequency and a second inductor of the series pair has a high inductance and low self-resonant frequency. The low inductance, the high self-resonant frequency, the high inductance and the low self-resonant frequency being each determined to locate a filtering cutoff point between the voiceband modem operating frequency band and the home phoneline operating frequency band.

In yet still another embodiment a method and apparatus for coupling a voiceband modem circuit, a digital subscriber line circuit and a home phoneline circuit to a common phoneline connector is provided, the common phoneline connection having a ring line connection and a tip line connection which couples a ring/tip line pair to a subscriber loop circuit, the voiceband modem circuit operating in a voiceband modem operating frequency band and having a voiceband modem interface ring line and a voiceband modem interface tip line, the digital subscriber line circuit operating in a digital subscriber line operating frequency band and having a digital subscriber line interface ring line and a digital subscriber line interface tip line, the home phoneline circuit operating in a home phoneline operating frequency band and having a home phoneline interface ring line and a home phoneline interface tip line. The voiceband modem

interface ring line, the digital subscriber interface ring line and the home phoneline interface ring line are coupled in parallel to the ring line. The voiceband modem interface tip line, the digital subscriber interface tip line, and the home phoneline interface tip line being coupled in parallel to the tip line connection. The coupling the voiceband modem interface ring line, the digital subscriber interface ring line and the home phoneline interface ring line and the coupling the voiceband modem interface tip line, the digital subscriber interface tip line and the home phoneline interface tip line is by inserting, between the ring line connection and the voiceband modem interface ring line and between the tip line connection and the voiceband modem interface tip line, a series pair of inductors. A first inductor of the series pair has a low inductance and a high self-resonant frequency and a second inductor of the series pair has a high inductance and low self-resonant frequency. The low inductance, the high self-resonant frequency, the high inductance and the low self-resonant frequency are each determined to locate a filtering cutoff point between the voiceband modem operating frequency band and the digital subscriber line operating frequency band.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1a - 1e show in block diagram form home networking environments within which the present invention can be implemented.

Figure 2 shows a frequency diagram in accordance with an implementation of the present invention.

Figures 3 - 5 show in block diagram form overviews of representative voice band modems with which the present invention may be implemented.

Figure 6 shows in block diagram form a combination phone networking transceiver and voiceband modem with which the present invention may be implemented.

Figures 7 - 8 show in block diagram form a combination phone networking transceiver, DSL modem and voiceband modem with which the present invention may be implemented.

Figure 9 shows in circuit diagram form a depiction of a realistic inductor.

Figure 10 shows in block diagram form an embodiment of the present invention.

Figure 11 shows in block diagram form a more detailed depiction of an embodiment of the present invention.

Figures 12a and 12b show in circuit diagram form a more detailed depiction of an embodiment of the present invention.

Figure 13 shows in block diagram form a further implementation of an embodiment of the present invention.

#### DETAILED DESCRIPTION OF THE INVENTION

Fig. 2 depicts the typical frequency plans used by voiceband modems, HPNA, and one example of DSL (e.g., ADSL), over telephone wires, such as the system depicted in Fig. 1e. Voiceband modems would occupy frequency band 111 (300 - 4000Hz). ADSL upstream would occupy frequency band 113 (26 - 138kHz). ADSL downstream would occupy frequency band 115 (138kHz - 1.104MHz). An HPNA implementation, such as the Broadcom Corporation family of iLine (tm) family of controllers, would occupy frequency band 117 (4 - 10mHz).

Generally, the DSL service and the voiceband modem will not be used simultaneously. However, as voiceband modems are used in facsimile transmissions, a voiceband modem connection for fax transmission may occur while the DSL service is in use. Also, in some residential applications, the DSL service may be used to access the Internet in general (for personal use), but a voiceband modem (e.g. V.90) may be used to connect to one's place of work for security reasons. In some cases, the DSL service may be inaccessible due to routing problems at the local telephone service provider or internet service provider (ISP) but the DSL signal may still be present on the metallic pair (e.g., transmitting IDLE patterns). In these cases, it is desirable that the performance of the voiceband modem be not adversely impacted by the presence of the DSL signal. Adverse impact means reduction in connection probability or in maximum data throughput. Since the DSL signals use higher frequencies than voiceband modems, it may be possible to use a simple low-pass filter (LPF) to attenuate the interfering DSL signal before the voiceband modem signal is sampled and quantized (digitized) by an analog-to-digital converter (ADC) for further processing by the receiving voiceband modem. However, the filtering must be performed before the ADC to avoid aliasing of the high-frequency signal into the range of frequencies used by the voiceband modem.

Referring now to Fig. 3, in many voiceband modems, typical data access arrangement (DAA) integrated circuit (IC) 118 and interface components 120 coupled between codec IC 122 and telephone line ring/tip lines 139, provide a high-voltage telephone line interface and protect other circuits in the modem from the DC loop current, the ringing signal, and surges. Low-voltage codec integrated circuit 122 contains an analog-to-digital converter (ADC) for the receive path, a digital-to-analog converter (DAC) for the transmit path, and all of



required low-pass filtering 124 to prevent aliasing and interference with higher frequencies. Since the filtering is implemented on an IC, it can be made at low cost.

Alternatively, required low-pass filtering 124 may be performed with discrete components between the DAA and the codec as shown in Fig. 4, or directly before the DAA, as shown in Fig. 5. In all of these cases, the filters may be implemented with small components that do not need to withstand high voltages across them or have high currents carried through them.

However, in some voiceband modem products, such as the Broadcom Corporation Model BCM94211 Voiceband Modem and Phoneline Networking Transceiver, the DAA IC derives its power source for operation from the telephone line itself. Some DC loop current is drawn by the DAA from the central office battery, and, as tip and ring may be reversed, an external diode rectifier bridge is used to ensure the correct polarity of the inputs. Ordinarily, when the voiceband modem takes the telephone line off-hook (active), no less than 6 Volts DC is present across the device. The voiceband modem signal at tip and ring of the telephone line is roughly 2 Volts peak-to-peak when the modem is transmitting. This AC signal sums with the DC bias from the line, resulting in a time-varying voltage which drops as low as 4 Volts. The DAA's need to see a specified minimum voltage at its power supply input pin, the rectifier bridge's two diode drops, in addition to other losses before the DAA, do not leave much margin for correct circuit operation. If a DSL upstream signal is added across tip and ring and not attenuated prior to the rectifier bridge, it is likely that the DAA will not get a clean source of line power, and the voiceband modem will fail to connect or connect at a lower rate.

One straightforward solution to the problem would appear to involve installing a passive POTS microfilter at the input to

the voiceband modem device. These microfilters are commonly installed by telephone companies providing splitterless DSL service, and they are attached either at the wall jack or the telephony device to protect the telephony device from high-frequency interference. This would appear to be a feasible, if expensive, solution provided that the voiceband modem is not a "combo" device, in which, for example, a voiceband modem and a phoneline networking transceiver are combined on one printed circuit board and connected to the phone line with a single connector. Fig. 6 shows an example of such a combo device, wherein phoneline networking transceiver 130 for an HPNA implementation and voiceband modem 132 are coupled in parallel to POTS phoneline RJ-11 connector 134 at ring/tip lines 139. Similarly, a combo device could also be expanded to include a voiceband modem, a DSL modem, and a phoneline networking transceiver on one printed circuit board. Fig. 7 shows an example of such an expanded combo device, wherein phoneline networking transceiver 130, voiceband modem 132 and DSL modem 136 are coupled in parallel to POTS phoneline RJ-11 connector 134 at ring/tip lines 139.

Referring to Fig. 8, another straightforward solution would appear to involve merely adding two high-valued inductors (e.g. 5 mH) 140a, 140b in series with each of the ring/tip lines 139 connections of the implementation depicted in Fig. 7. If the value of these inductors is sufficiently-high, the high-frequency ADSL interfering signal will be sufficiently-attenuated before the rectifier bridge. However, the inductors must also not have a value high enough to significantly attenuate the voiceband modem signal, which occupies spectrum to 4000 Hz. The problem with this solution, referring to Fig. 9, is that a practical inductor 150 behaves more like ideal capacitor 152 in parallel with the series combination of resistor 154 and ideal inductor 156. Therefore, at higher

frequencies, above the so-called "self-resonant frequency"  $\omega_r = 1/\sqrt{LC}$ , the inductor's impedance actually drops with frequency, acting like a capacitor. The self-resonant frequency of the larger inductors tend to be low, in the hundreds of kHz.

5 However, there is presently no commercially-available technique for building low-cost, high self-resonant frequency large inductors. Accordingly, the front-end of the voiceband modem with these large inductors would start to look like a short circuit at higher frequencies, affecting the performance of both  
10 the DSL downstream band and also the higher-frequency home phoneline network. Also, there arises a conflict between the need for a high inductance value, such as 5mH, and the ability to handle a large DC current, such as 125mA. (These inductors  
15 must be able to pass a DC subscriber loop current of up to ~ 125mA without saturating when the DAA goes off hook.) These conflicting requirements lead to bulky and expensive inductors and therefore it is important to minimize the filter complexity and the number of these inductors required.  
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Referring now to Fig. 10, phoneline networking transceiver 130 and voiceband modem 132 are coupled to RJ-11 connector 134 at ring/tip lines 139 (as in Fig. 6). However, between voiceband  
25 modem 132 and the ring/tip connections at ring/tip lines 139, low-valued inductor 200 (e.g. 47  $\mu$ H) with high self-resonant frequency (tens of MHz) is placed in series high-valued inductor 202 (e.g. 5 mH) with low self-resonant frequency (hundreds of kHz  
30 to a couple of MHz) at both tip and ring lines. Since the impedance of the ideal inductor is directly proportional to frequency, the use of the lower-valued, high-self-resonant-frequency inductor sufficiently protects the higher-frequency services from unwanted attenuation due to insertion of this  
35 device into the phone network. However, the high-valued, low-self-resonant-frequency inductor protects the voiceband modem receiver, and its line power source, from the ADSL upstream

signal. Inductors 200, 202 are in essence valued to locate the filtering (cutoff) point between voiceband modem band 111 and ADSL upstream band 113 as shown in Fig. 2. At frequencies below the self-resonant frequency the inductors look like a true inductor, while at frequencies above the self-resonant frequency the inductors look like a capacitor. In the representative embodiment of series inductances as described above, the 5mH inductor (a relatively high value inductance dictated by the filtering frequency desired) has a low-resonant frequency whose inductive properties for the voice modem cutoff frequency are extended out to a higher frequency than can be obtained by an individual 5mH inductance. This inductive properties extension is achieved by providing the additional 47 $\mu$ H inductor in series with the 5mH inductor. In essence, the combination merely has a 5mH inductance value because of the relatively small  $\mu$ H amount being added to a mH amount. Therefore, when the 5mH inductor starts to operate like a capacitor, the 47 $\mu$ H inductor will operate like an inductor and extend the inductive behavior out to a higher frequency. Therefore, the low-value inductor is low relative to the 5mH (high value) inductor dictated by the filtering cutoff requirement, e.g., the values being of a two order of magnitude difference in values. The two orders of magnitude in inductor value will produce approximately two orders of magnitude difference in self-resonance frequency value.

Referring to Fig. 11, the principal components of an embodiment of the combo device depicted in Fig. 10, for example, the Broadcom Corporation Model BCM94211, is shown implementing the present invention. Phoneline networking transceiver 130 includes bandpass filter/magnetics circuit 140 coupled between ring/tip lines 139 and analog front end 142. Transceiver and modem interface 144 is coupled to analog front end 142. Voiceband modem 132 includes line interface/protection circuit

150 coupled between high-valued inductor 202 and DAA IC 152. Voiceband modem 132 also includes codec 154 coupled between DAA IC 152 and transceiver and modem interface 144.

Referring now to Figs. 12a and 12b, the interfaces between ring/tip lines 139, inductors 200, 202, interface/protection circuit 150 and bandpass filter/magnetics circuit 140 of Fig. 11 are shown in more detail. In Fig. 12a, the interface between ring/tip lines 139, and interface/protection circuit 150 is shown in more detail. Interface/protection circuit 150 is coupled to codec 154 (shown in Fig. 11) through standard DAA IC 152 and with ring/tip lines 139 through pairs of inductors 200, 202. Interface/protection circuit 150 includes diode protection bridge 160 for voltage polarity sensing. Diode protection bridge 160 includes filtering capacitor 162 and forms the low-pass filtering with the pairs of inductors 200, 202. Interface/protection circuit 150 also includes zener diode protection device 164. Interface/protection circuit 150 includes transistor switch sub-circuits Q2, Q3, Q4 with accompanying biasing resistors. DAA 152 includes by-pass capacitor sub-circuits 166, 168 which are in parallel with filtering capacitor 162. However, the capacitance values of by-pass capacitor sub-circuits 166, 168 being in the pf range add little to the capacitance provided by filtering capacitor 162 which is in the uf range. In Fig. 12b, bandpass filter/magnetics circuit 140 includes transformer T1 coupled to transmit TX and receive RX lines of analog front end 142. Bandpass filter/magnetics circuit 140 includes filter 141 and noise suppression capacitor 143 and is coupled to ring/tip lines 139. Ring/tip lines 139 connect to RJ-11 connector 134. Ring/tip lines 139 include therebetween over-voltage protection device RV1.

Another possible embodiment of this invention is set forth in Fig. 13, wherein an expanded combo device of that shown in

Fig. 7 is depicted. Phoneline networking transceiver 130, voiceband modem 132 and DSL modem 136 are coupled in parallel to POTS phoneline RJ-11 connector 134 at ring/tip line 139. In accordance with the present invention comparable inductors 200 and 202 can be interfaced with voiceband modem 132 and provide appropriate filtering such that interference signals from phoneline networking transceiver 130 and/or DSL modem 136 will not impact the operation of voiceband modem 132 in the same manner as described above for the combo device having merely the phoneline networking transceiver and the voiceband modem.

Therefore, in accordance with the present invention a circuit is provided for attenuating an interfering DSL signal within a voiceband modem while passing the voiceband modem signal to the remainder of the voiceband modem receiver path with negligible loss. The circuit is inserted at the line input to the modem, protecting line-powered DAAs from interference.

It also does not affect the performance of the upstream or downstream DSL signals or the performance of home networks that share the same phone line, as it does not present a near short-circuit input impedance at higher frequencies. In addition, it enables devices to be implemented that combine voiceband modem, DSL, and/or home phoneline networking functionality.